Finding supernovae at the reionization era with Subaru and WFIRST

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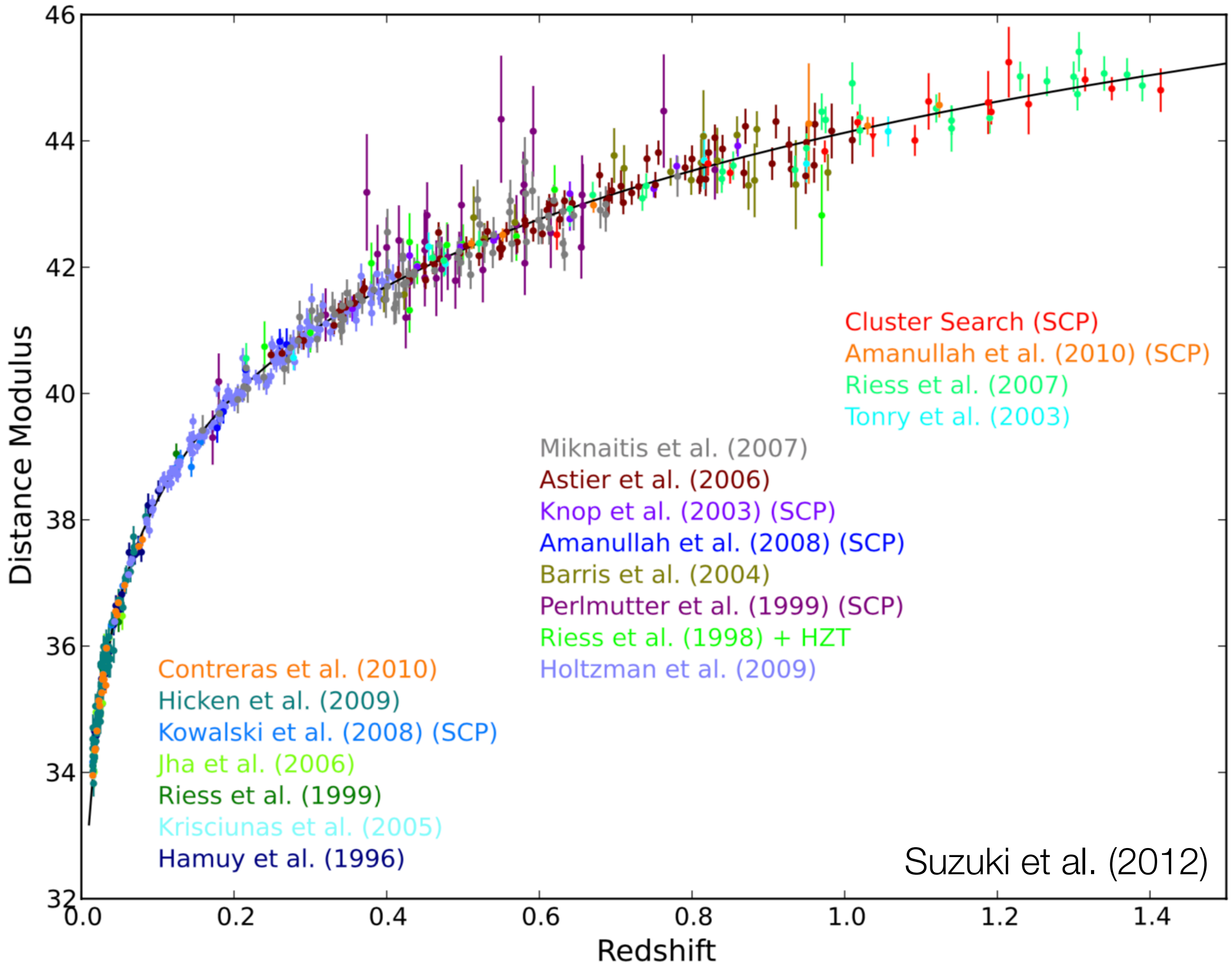
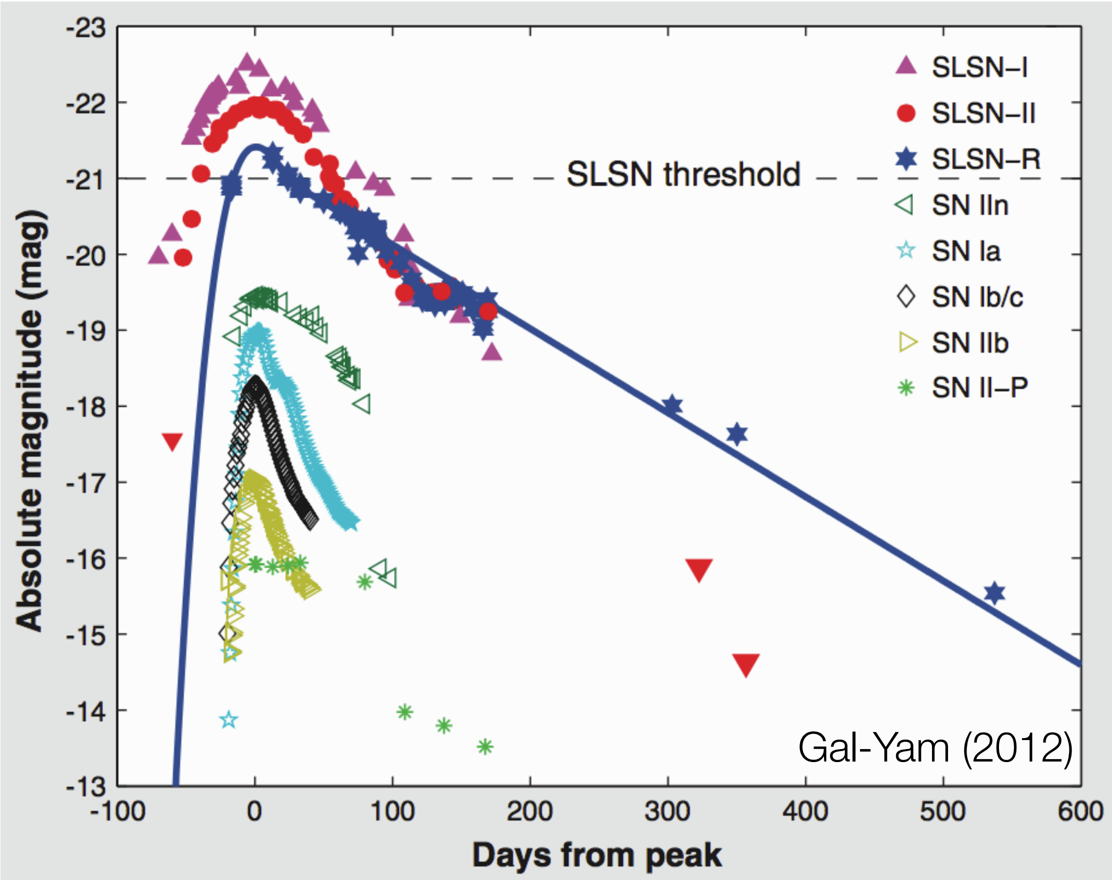
Exploring the early Universe with supernovae

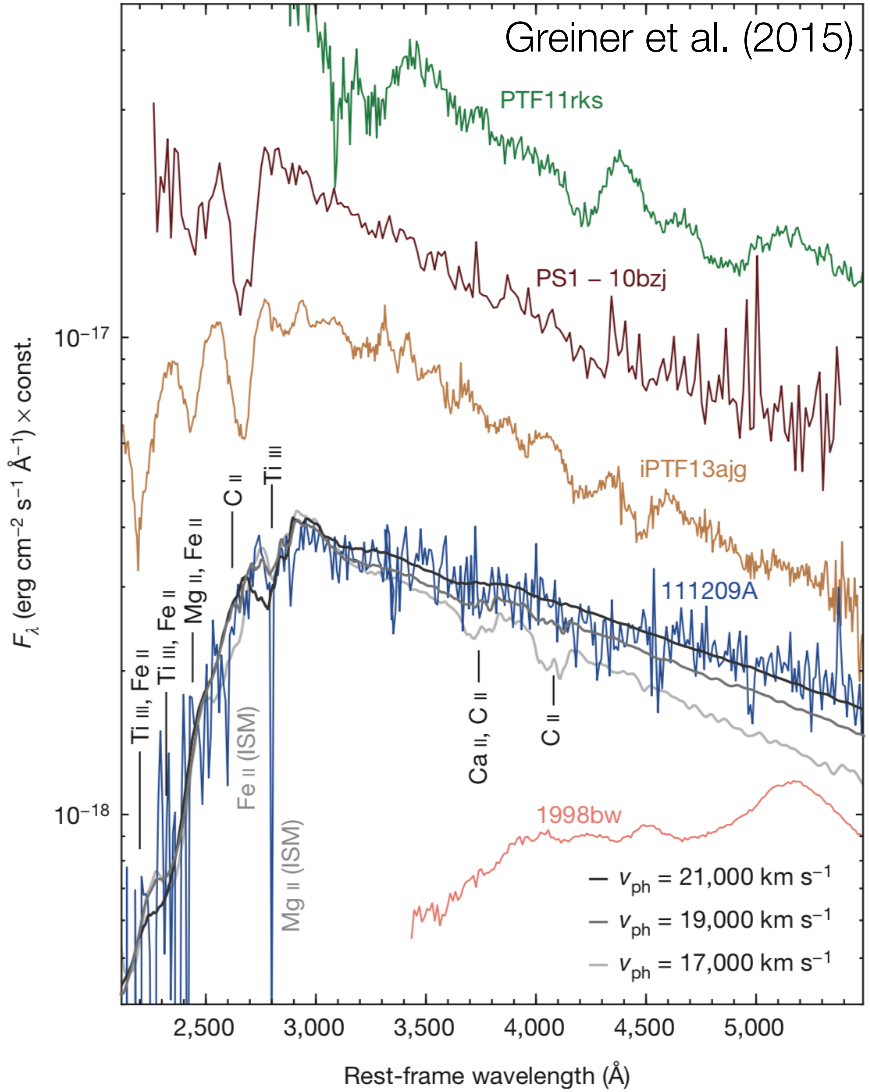
- A classic tool: Type Ia supernovae



Exploring the early Universe with supernovae

- A new class of bright supernovae: superluminous supernovae
  - bright and blue

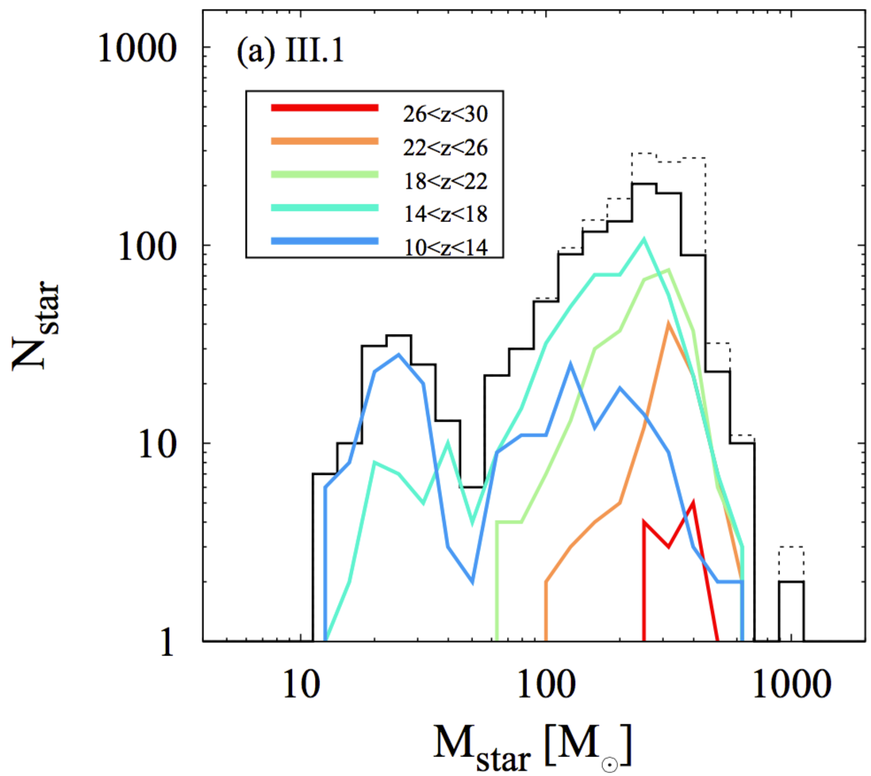




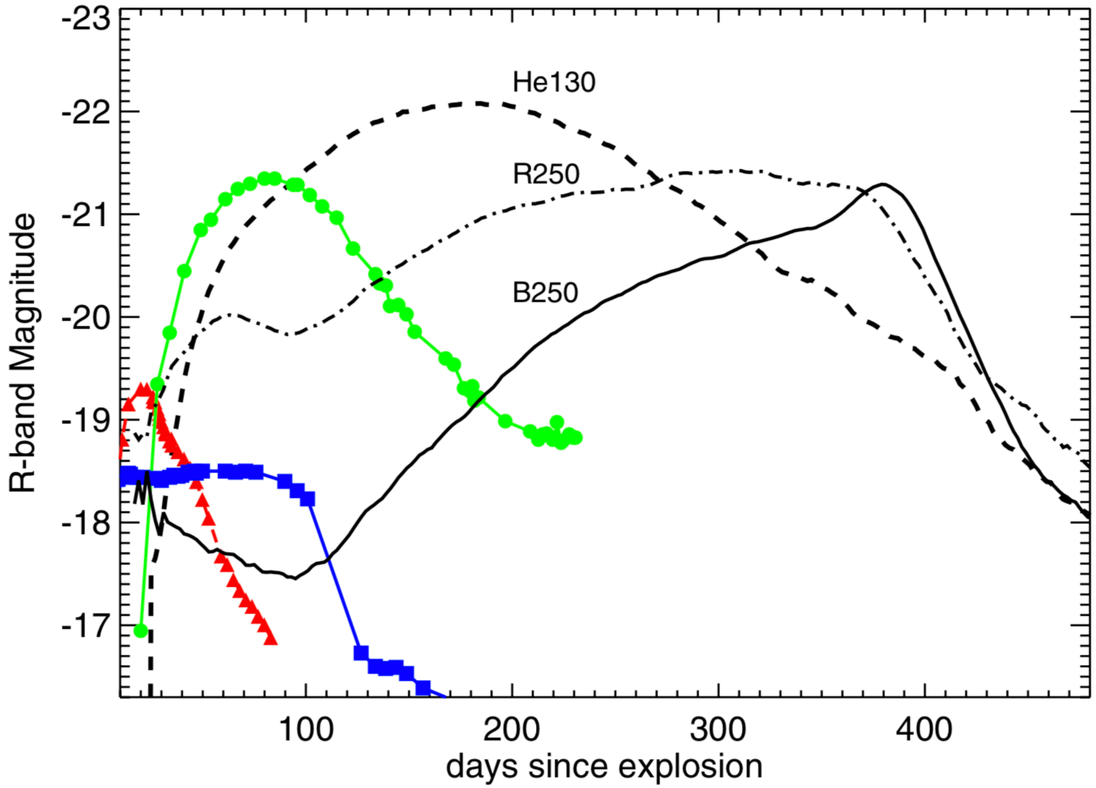
Exploring the early Universe with supernovae

- Predicted bright supernovae: pair-instability supernovae
  - they probably appear in the early Universe
    - metal poor environment required
  - first stars between ~150 Msun and ~250 Msun

Hirano et al. (2014)

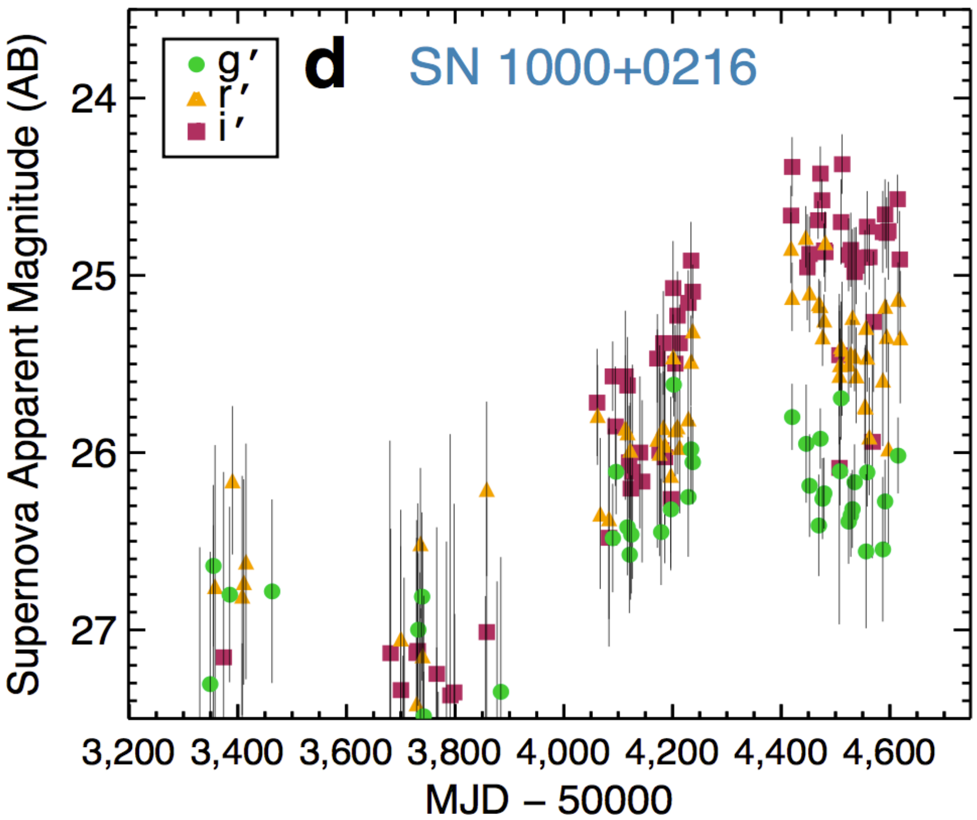


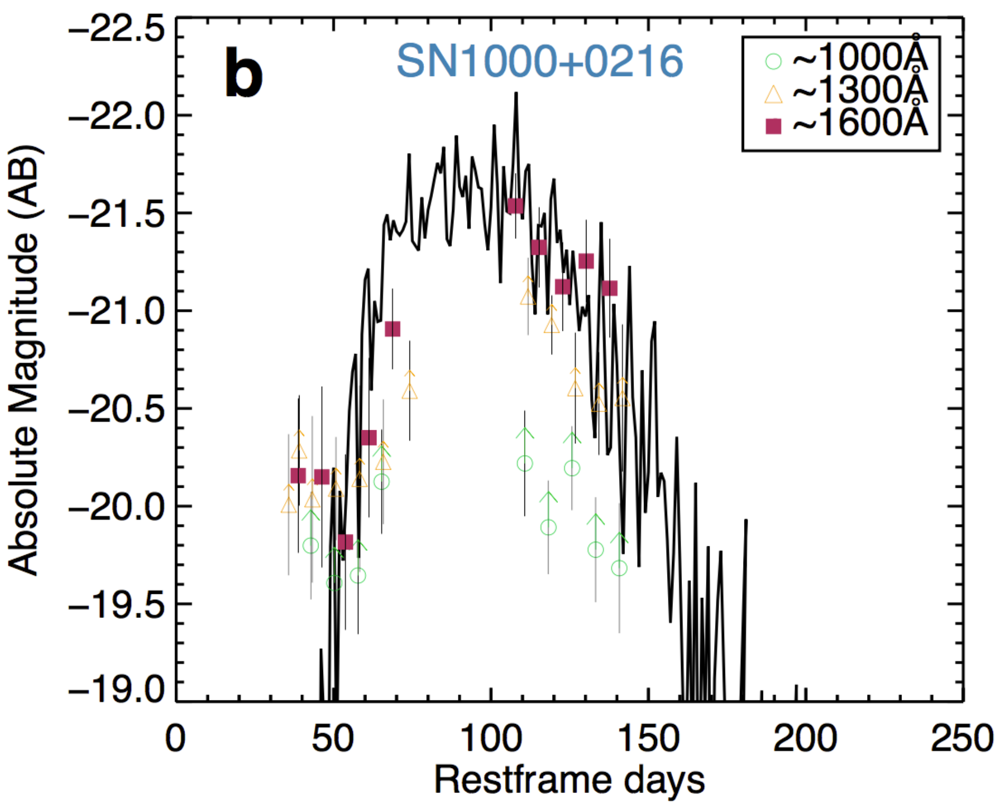
Kasen et al. (2011)



High-redshift supernovae

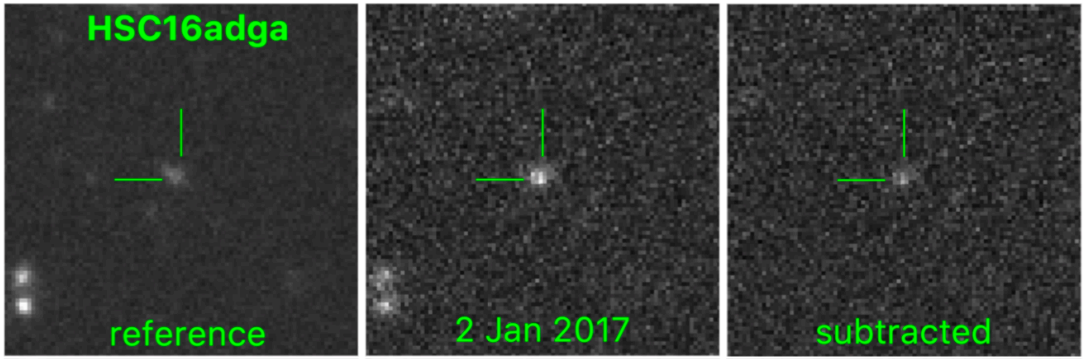
- Highest redshift supernovae so far (Cooke et al. 2012)
  - z = 3.9
  - found by CFHT/MegaCam
  - no supernova spectrum, redshift from host galaxy spectroscopy

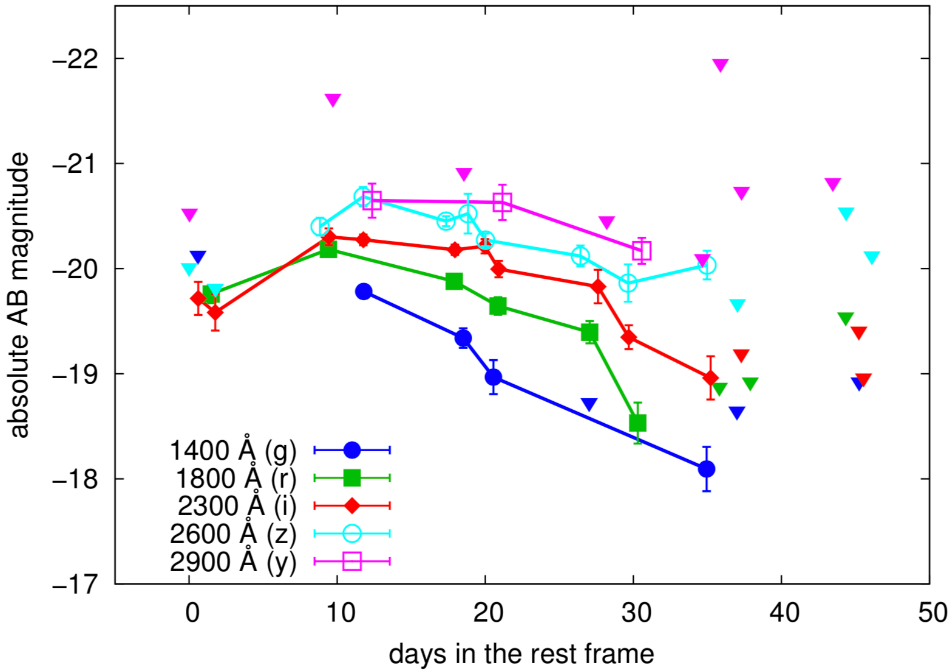




High-redshift supernova survey with Subaru/HSC

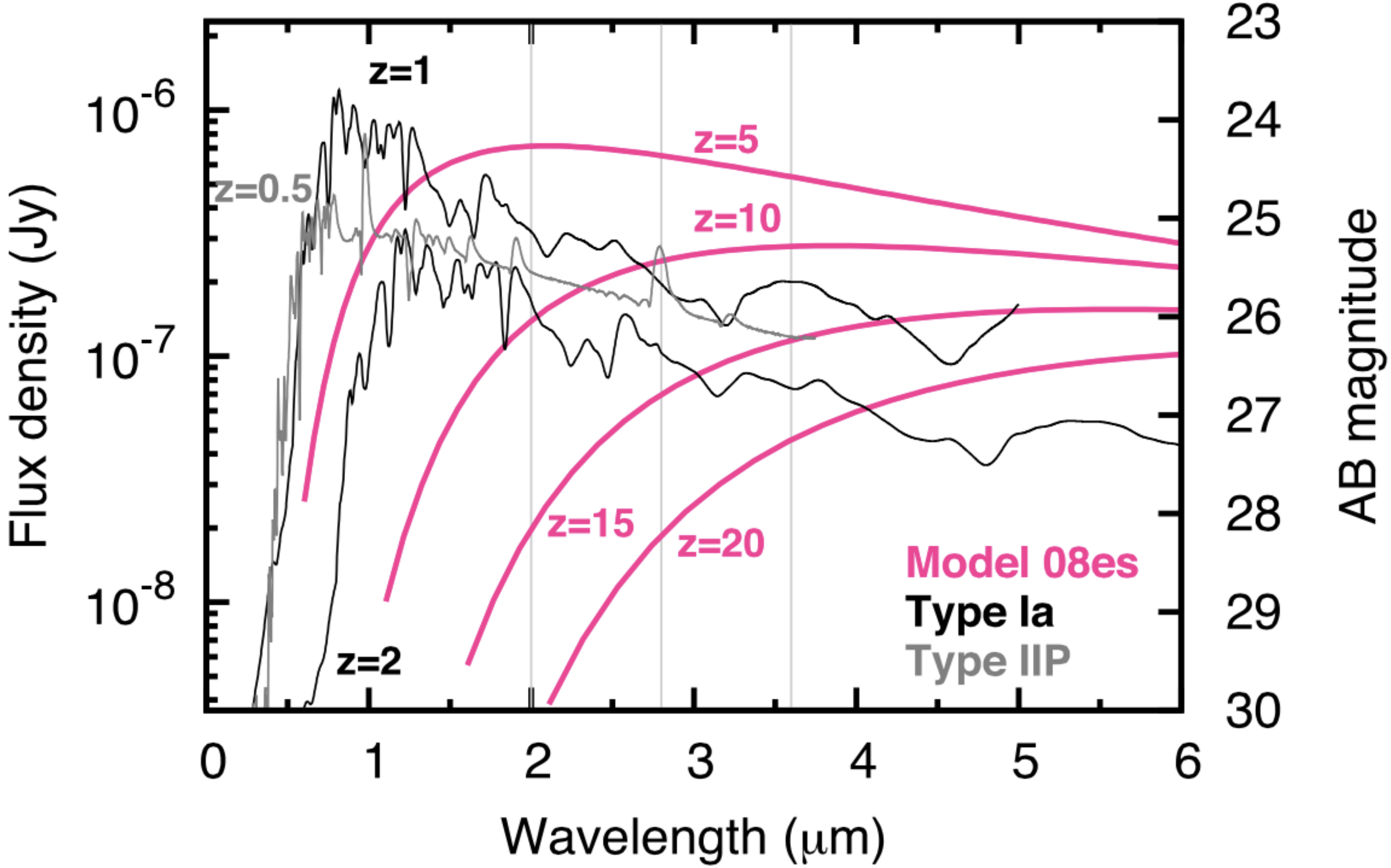
- Subaru HI-Z sUpernova CAmpaign (SHIZUCA, 静か ‘quietness’)
  - z = 2.399 (spectroscopically confirmed) and beyond!





Moriya et al. (2018)

Limits of optical surveys



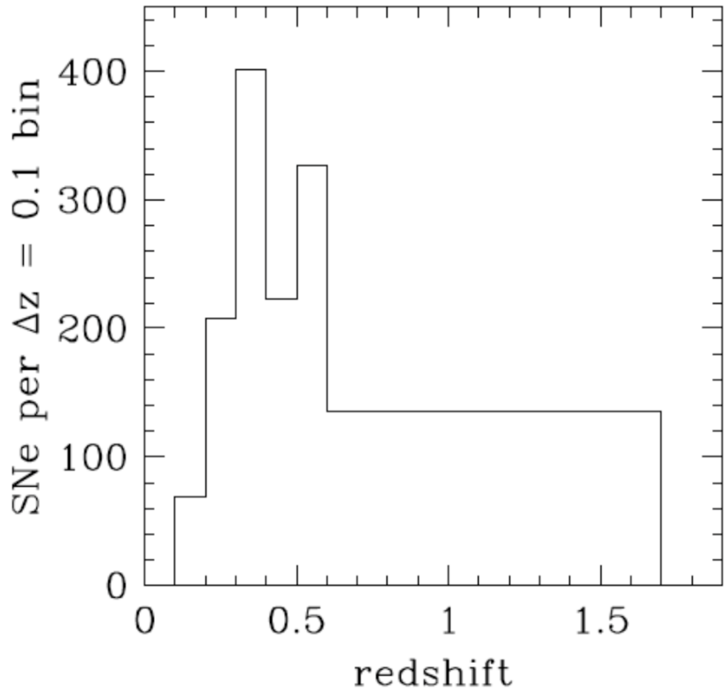
Tanaka, Moriya, & Yoshida (2013)

Transient survey in WFIRST

- WFIRST transient survey plan in Spergel et al. (2015)

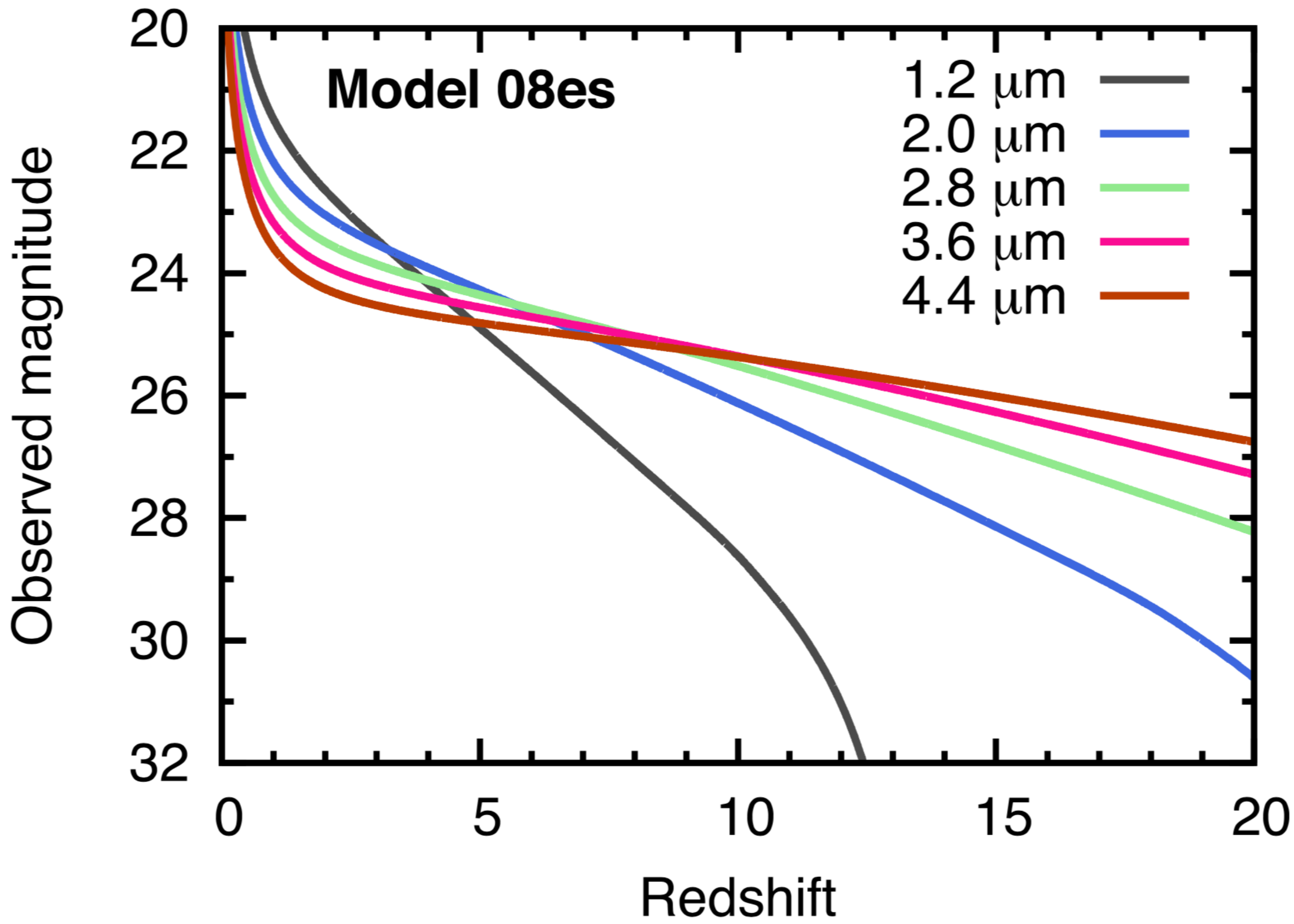
layer	area (deg2)	filters	depth / visit	targeted SN Ia
wide	27.44	Y, J	24.5 mag	z < 0.4
medium	8.96	J, H	25.5 mag	z < 0.8
deep	5.04	J, H	26.5 mag	z < 1.7

Spergel et al. (2015)



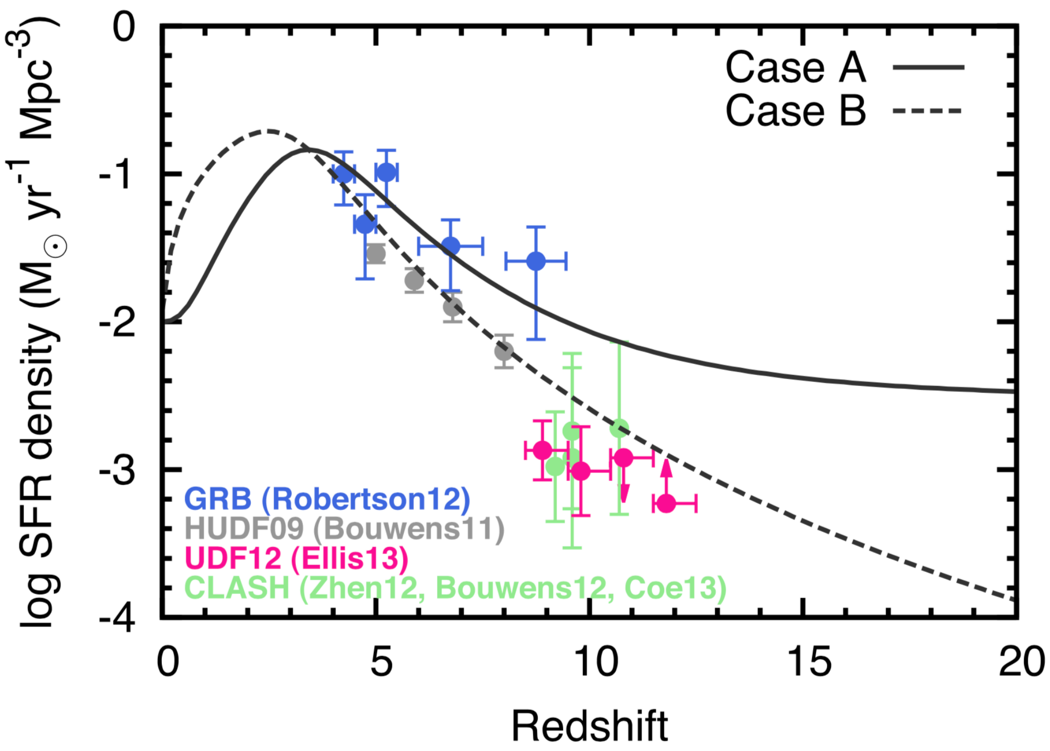
Finding superluminous supernovae with WFIRST

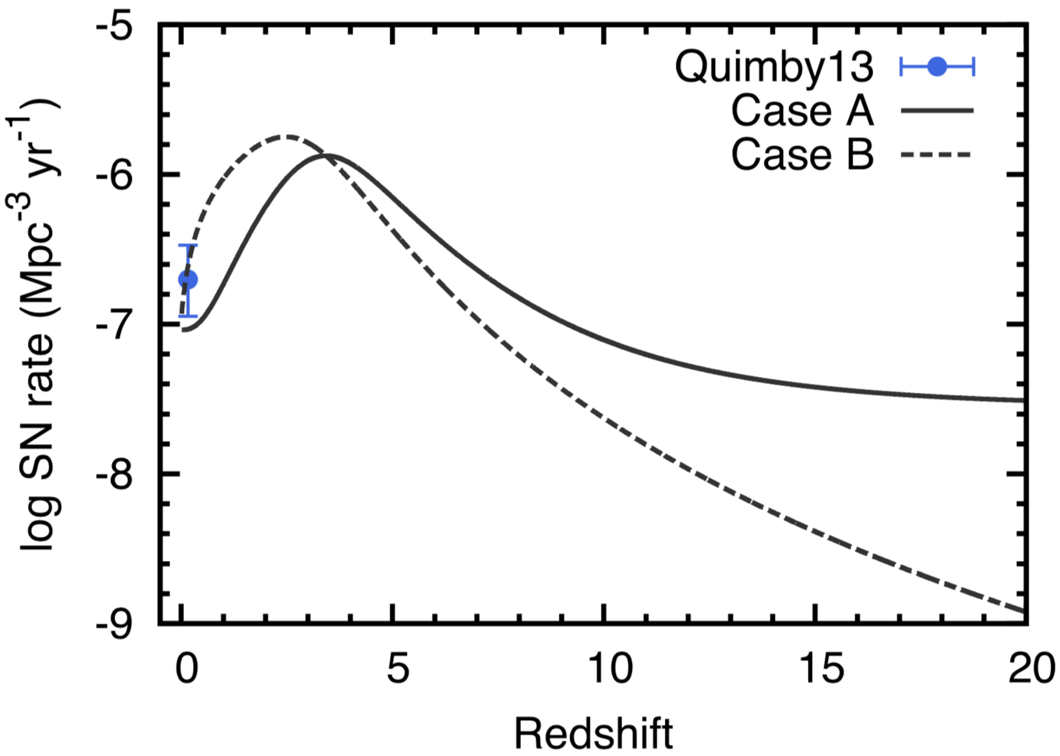
- Expected brightness of high-redshift superluminous supernovae



Tanaka, Moriya, & Yoshida (2013)

Towards the reionization era: rate estimates

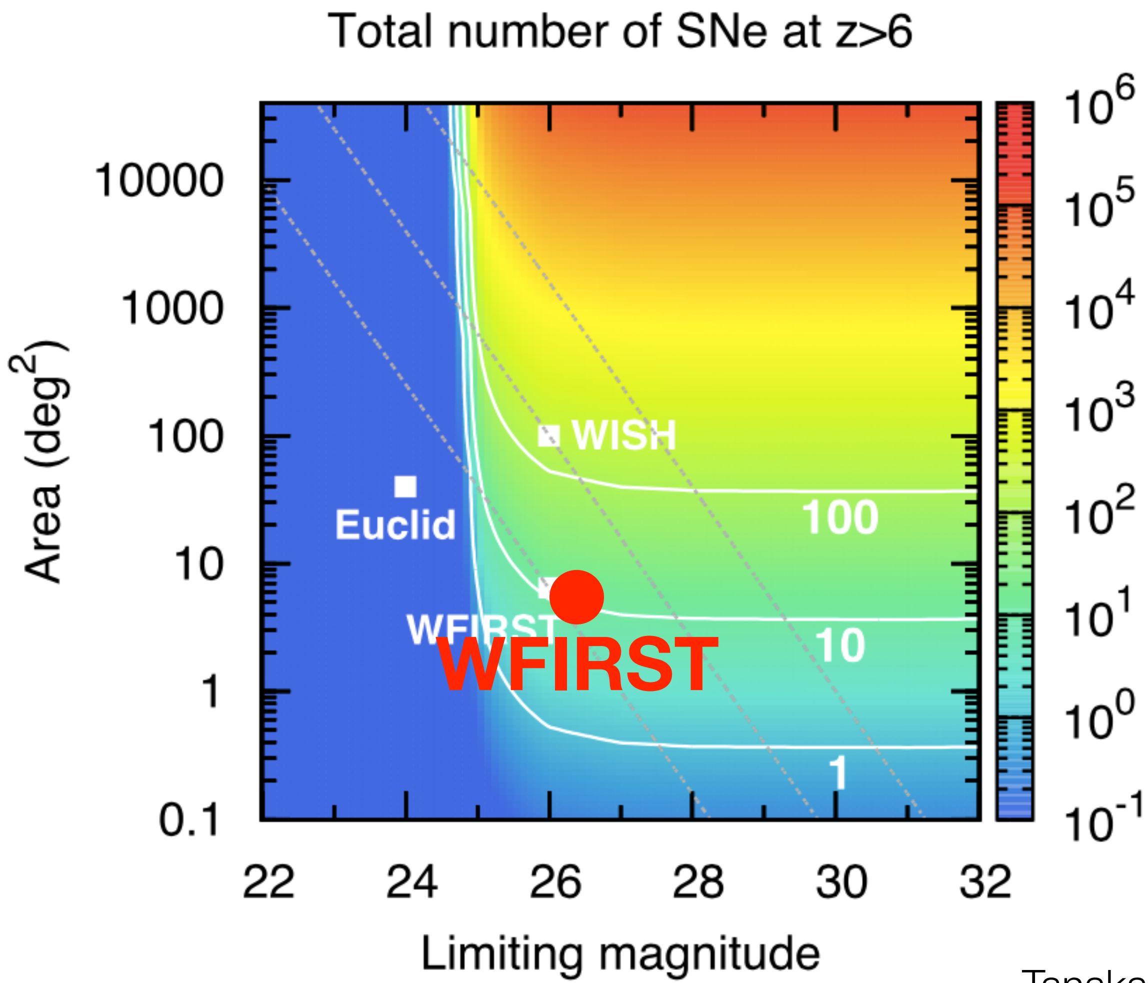




Tanaka, Moriya, & Yoshida (2013)

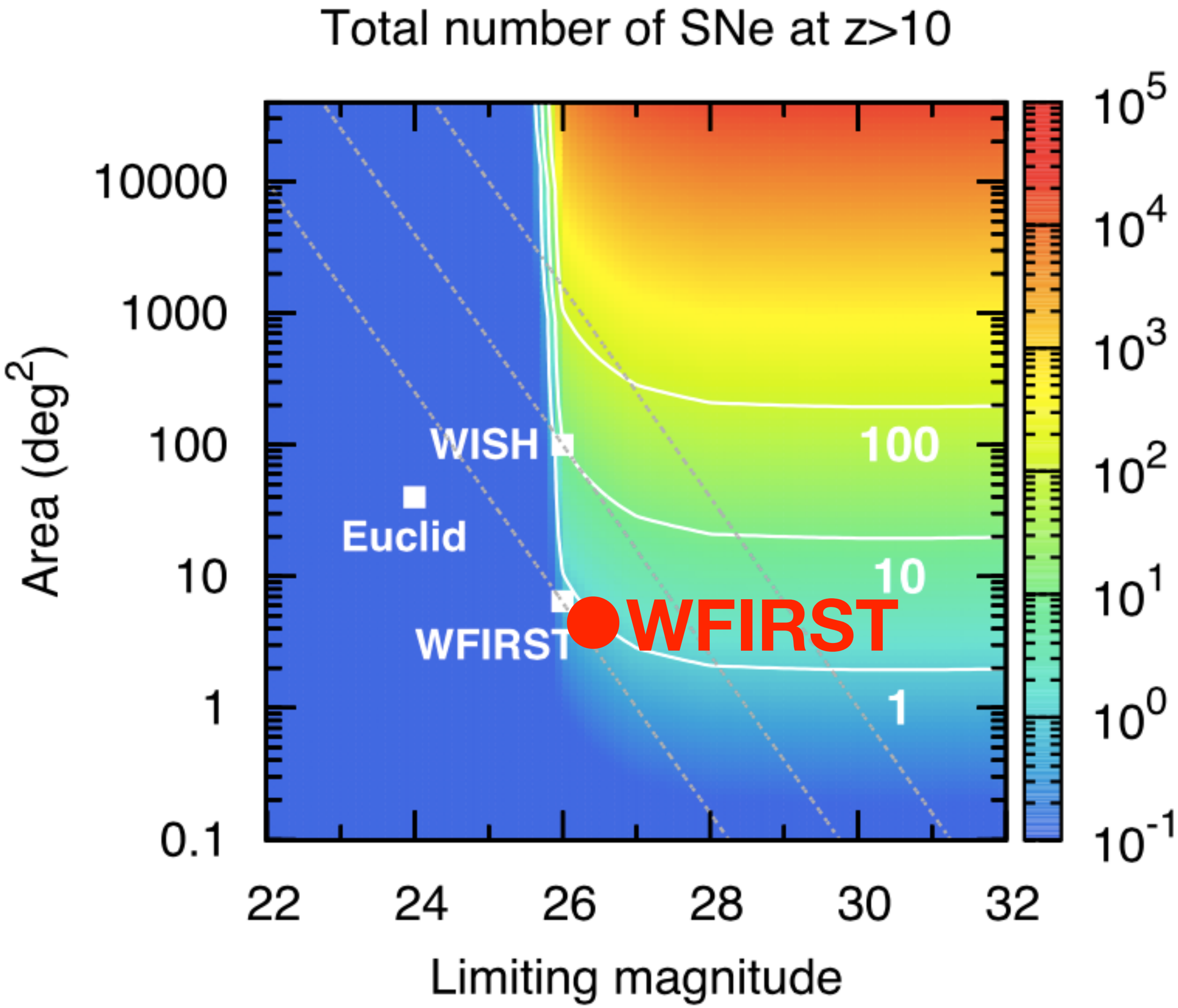
Towards the reionization era: rate estimates

- Superluminous supernova detection expectation at z > 6
  - + pair-instability supernovae!



Tanaka, Moriya, & Yoshida (2013)

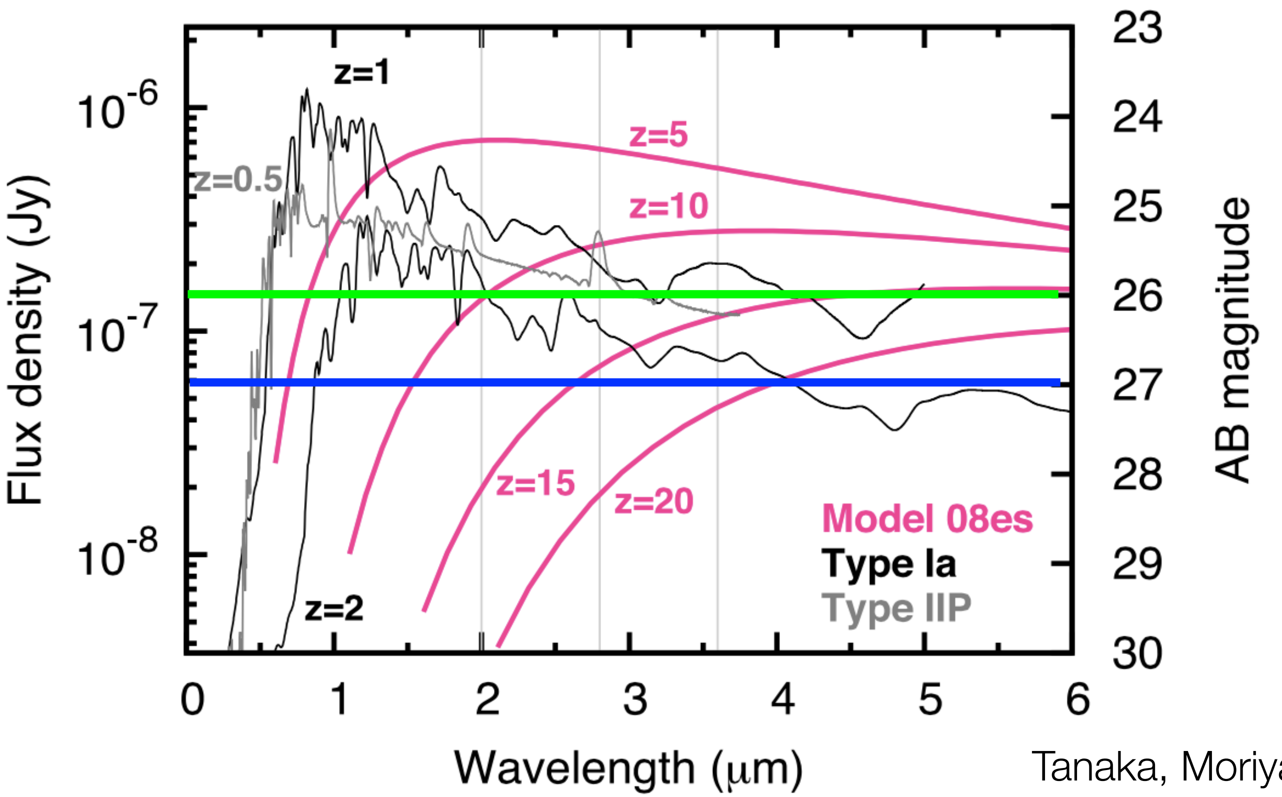
z > 10: towards the first supernovae



Tanaka, Moriya, & Yoshida (2013)

Selecting z > 6 supernovae using Subaru/HSC

- high-redshift supernovae are very faint in optical
  - if we have deep optical imaging simultaneously, z > 6 supernovae will not be detected in optical: efficient candidate selection
    - e.g., “z drop” supernovae are z > 6 candidates
  - + other information (e.g., host)



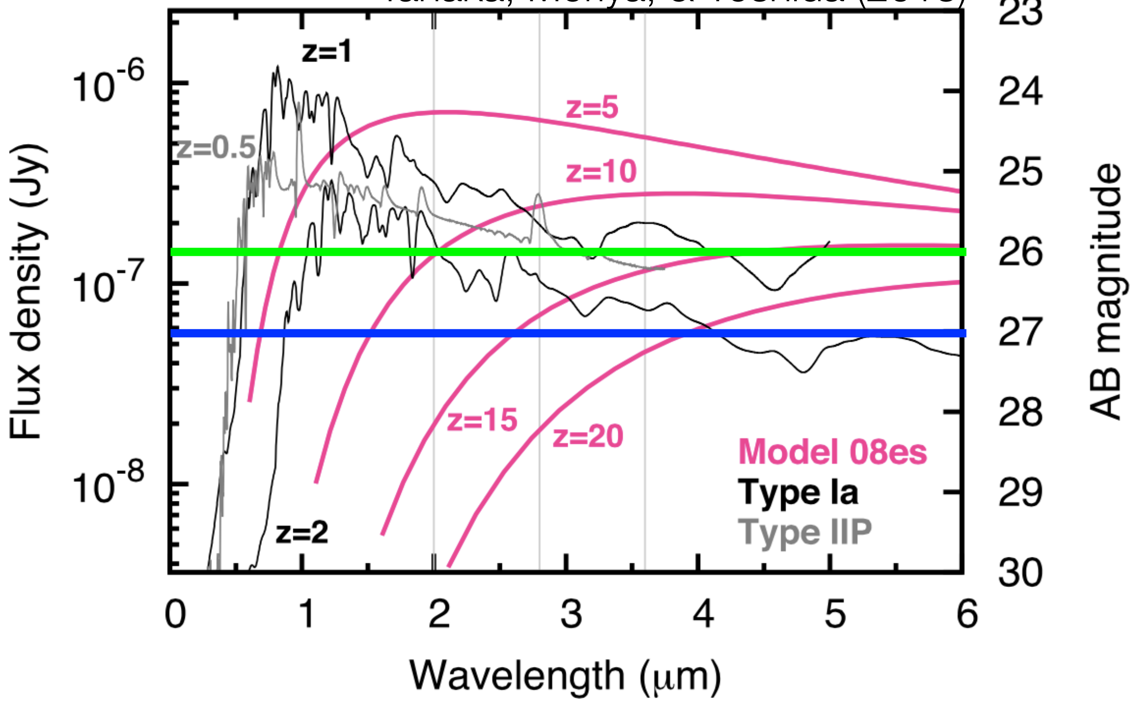
Tanaka, Moriya, & Yoshida (2013)

Why Subaru/HSC?

- 27 mag limits in optical is desired
  - LSST will not go down to 27 mag in a single epoch
- Subaru/HSC can provide a VERY deep optical limits in each epoch
  - 27 mag in z band: ~ 1 night/1.8 deg2 for S/N = 5
    - ~ 3 nights for 5 deg2 (deep SN field)
    - x several epochs (~ 10 nights in total)

filt	average gap (days)	exposure time (min)	5σ limiting mag
LSST-DDF			
u	29	6	24.8
g	6	5	25.4
r	6	10	25.7
i	6	10	25.2
z	6	9	24.6
Y	6	10	23.3

Tanaka, Moriya, & Yoshida (2013)



Summary

- Supernovae at the reionization era (!) can be discovered with WFIRST + Subaru/HSC
  - WFIRST will find ~ 10 supernovae at $z > 6$ in the deep SN layer
  - valuable information on massive star formation in the early Universe can be obtained!

- coordinated very deep observations with Subaru/HSC
  - look for "z drop" transients, for example
    - 27 mag for 5 deg2 in z band x several epochs: ~ 10 nights
    - difficult with LSST
    - possible follow up by TMT and JWST